September 1, 2003
Word count 1525

Volcanic gas workshop fosters international focus on state of the art measurement techniques.

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Volcanic gas emissions can often be interpreted as signals from deep within the Earth. The study of volcanic gases increases our understanding of how magmatic systems behave and in some cases it can be used as a predictive tool for eruptive activity and associated hazards. Not only are we concerned with the dangers of large eruptions, but if large volumes of gas are released, the gases themselves can pose a hazard to communities surrounding a volcano. The environmental impacts of volcanic gas emissions are observed on local scales, and the significant global contribution to the atmosphere is also an area of current interest since it relates to global climate change. As we still have much to understand about volcanic eruptions and the environmental impacts of volcanic gas emissions, scientists benefit from working together to improve instrumentation and monitoring techniques.

Every three years, volcanologists from around the world gather at selected volcanoes to compare and improve volcanic gas monitoring methods and to pool their knowledge as a scientific community. This year, the Eighth Field Workshop on Volcanic Gases, sponsored by the Commission on the Chemistry of Volcanic Gases (CCVG) and the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) was held in Central America from 25 March to 2 April, 2003. With the collaboration of the Instituto Nicaragüense de Estudios Territoriales (INETER) and the Observatorio Vulcanológico y Sismológico de Costa Rica (OVSICORI-UNA), the workshop attendees converged at Masaya, Cerro Negro and Mombotombo volcanoes in Nicaragua and at Póas volcano in Costa Rica. The workshop attracted over 80 researchers from 20 countries, along with their various instruments and capabilities. The overall goals of the workshop not only included perfecting techniques and sharing ideas, but also working together to develop an integrated approach to volcanic gas monitoring.

Traditionally, volcanic gas geochemistry has focused on samples collected from high-temperature fumaroles. Recent technological developments and discoveries over the past decade have advanced the measurement and monitoring of volcanic gas emissions such that this gas workshop was the largest and most varied to date. In addition to sampling fumaroles in the Central American volcanoes, research groups focused on carbon dioxide soil gas measurements, filter sampling of volcanic plumes, and new ground-based remote sensing technologies.

Researchers interested in fumarole emissions compared different approaches to sample collection and their various analytical techniques which have evolved over recent years. These samples give us our best look at trace elements transported in volcanic gases. In addition to the long list of inorganic species known to be emitted by volcanoes, organic compounds are now being identified which are stable in these hot acidic gases. Although valuable information is gained from fumarole sampling, it can be dangerous and requires the researcher to wear protective gear, including a full-face respirator. Due to such hazards, effort has been placed on complementary techniques of volcanic gas monitoring, such as remote sensing.

The most notable change in volcanic gas measurements has been the development of remote sensing techniques. For several decades, volcanologists have relied on the correlation spectrometer (COSPEC) for ground-based remote sensing of volcanic sulfur dioxide. However, miniature differential optical absorption spectrometers (e.g., mini-DOAS and FlySpec) have emerged as new tools that provide sulfur dioxide data similar to that of COSPEC. The low cost and small size are major advantages of these instruments, as arrays of several instruments can be deployed around volcanoes. Since a large number of spectrometers were present at the Workshop, a number of interesting multi-instrument experiments were attempted such as estimation of wind speed for the volcanic gas plume. The spectrometers also provide promise of being developed into a multi-gas sensor to detect such species such as ozone and BrO (Bobrowski et al., 2003), thus opening new perspectives to better understand the effects of volcanic emissions on the atmosphere's chemistry.

Quantification of diffuse gas emissions (e.g., carbon dioxide) is important for determining the total volcanic gas budget and for monitoring purposes. While other volcanic gases tend to be more reactive, carbon dioxide can degas diffusively and provide details of subsurface characteristics such as locations of faults that are not visible on the surface. In some cases, a change in flux patterns could be an indication of subsurface magma movement. Six research groups compared individual carbon dioxide flux measurements and methods to estimate total area emissions.

The Workshop field measurements were initiated at Masaya volcano in Nicaragua, which is of particular interest due to its basaltic composition that is unusual for a subduction zone setting such as that in Central America. Masaya has been frequently active since the arrival of the Spanish Conquistadors and exhibits cycles of major non-eruptive degassing crises (Stoiber et al., 1986). The summit is easily accessible by road so that even large instruments can be positioned at the edge of Santiago crater, a 250 meter diameter active crater which has been degassing continually since 1993. Looking into the 600 meter deep crater, gases can be seen emanating from the vent formed by the April 2001 eruption, which threw boulders onto cars parked in the observation area. During the dry season between November and May, the wind predominantly blows from the east, and areas of damaged vegetation can be seen downwind of the volcano. The plume passes over several roads, allowing ground-based remote sensors to make traverses normal to the plume at multiple downwind locations. In addition, large quantities of carbon dioxide are discharged diffusely from a fracture zone located on the northeast flank of Masaya. Research groups thus had the opportunity to make comparative carbon dioxide flux measurements along this fracture zone.

Masaya did not offer opportunity to sample high-temperature fumaroles but its neighbors, Mombotombo and Cerro Negro volcanoes, are noted for their fumarolic activity. A group of "fumarolists" left the hotel at 3 AM, making the 5 hour ascent to the summit of Mombotombo and were rewarded with fumarolic temperatures of near 800˚ C. Temperatures of this magnitude are rarely found but are important since the high temperature suggests that the gases are coming directly from the magma and have not undergone extensive interaction with hydrothermal or meteoric fluids. The insight provided by these magmatic gases is important for long-term monitoring of Momotombo, as eruptions from this volcano are explosive in nature and have occurred at intervals of 3-85 years (Menyailov et al., 1986).

Many of the workshop attendees also spent a day conducting measurements and collecting samples on Cerro Negro volcano in Nicaragua, the youngest volcano in Central America. Not only is Cerro Negro one of the most active volcanoes in Nicaragua, it is one of only several cinder cones in the world that is known to have erupted more than once which makes it difficult to classify as a basaltic cone or composite volcano. In addition, the variability in its eruption style adds to the unusual nature of this volcano. The violent 1992 eruption propelled ash and gases as high as 7.5 km and caused the evacuation of 28,000 people. The 1995 eruption was less explosive and was characterized by a lava flow (Roggensack et al., 1997). Work by Roggensack et al. (1997) showed that the difference in behavior is related to the amounts of H_2O and CO_2 that were released prior to eruption. Therefore, long-term monitoring of CO_2 emissions at Cerro Negro may help characterize the amount of degassing prior to eruptions and could serve as a predictive tool. This is also a situation where diffuse soil degassing could be an important tool, as previous work found an anomalously high output of diffuse CO_2 (Salazar et al., 2001).

The second part of the Workshop was held in San Jose, Costa Rica, to focus on Póas volcano. Póas provided a strong contrast to the Nicaraguan volcanoes. It is andesitic and therefore more characteristic of the subduction zone setting of the Central American chain of volcanoes. The main gas plume of Póas emanates from the acidic crater lake and surrounding fumaroles. The crater lake at Póas is known for its low pH which was approximately 0.4 during the workshop (Martinez pers. comm.). Póas offered the unique opportunity for the different research groups to sample or remotely monitor its persistent plume, directly sample its fumaroles, and measure diffuse carbon dioxide emissions from an intra-crater terrace.

During the final day of the workshop, the participants met as three informal research groups to summarize and compile the knowledge gained during the workshop for high-temperature fumarole sampling, diffuse degassing, and ground-based remote sensing. Additionally, a fourth group met to consider current and future gas sampling approaches and initiatives for Central America and northern South America. This was an effort to build cooperation among volcanic gas scientists from the different countries in the region. Researchers are currently analyzing samples and data collected, with plans to make the results accessible to all workshop participants in a web-based format to integrate the different areas of volcanic gas monitoring as well as provide direct sampling data to validate remote sensing results.

The workshop was supported by IAVCEI, the US National Science Foundation MARGINS Initiative, the Central American Volcanic Hazard Project (ICSU/IAVCEI), and the NASA Solid Earth and Natural Hazards Program. We are grateful for their support.

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